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ALASKA OREGON WASHINGTON
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-217 January 1974

CHEMICAL CHARACTERISTICS OF SOME FOREST AND GRASSLAND SOILS OF NORTHEASTERN OREGON

II. Progress in Defining Variability in Tolo and Klicker Soils

by

J. Michael Geist, *Research Soil Scientist*

JUN 25 1974

ABSTRACT

Comparisons of Tolo and Klicker soil fertility indicated that Tolo soils have lower overall nutrient concentration levels. Organic matter, total nitrogen, and available phosphorus concentrations decrease sharply from upper to lower depths in all soil profiles, while certain other chemical characteristics increase. Variability in chemical properties differs by depth increment and specific chemical characteristic in both soils.

Grouping of soils according to overstory dominant vegetation showed that differences in several chemical properties were associated with these groups. Such results imply possible nutrient cycling differences among these plant communities which may have bearing on their ecological dynamics. Many similar chemical changes with depth gradient were noted between soil series and vegetative groupings.

Topsoil conservation practices should be stressed in heavy equipment use on both Tolo and Klicker soils. The data indicate that precautions are necessary in soil sampling, particularly if fertilization guides are to be developed. The results will also be useful in determining effects of forest management on soil chemical systems.

Keywords: Soil fertility, soil properties, soil management, Oregon.

INTRODUCTION

This paper reports progress in defining soil chemical properties and their variation for soils mapped within the Tolo and Klicker series. The data are part of a continuing effort to characterize upland soils in eastern Oregon. This information provides a reference base for measuring effects of overstory removal or other vegetative management, information on present fertility levels, and a basis for determining sampling requirements for resource inventory and future research studies. An earlier report contained results from single profile analyses of several forest and grassland soils but lacked information about variation of the properties determined (Geist and Strickler 1970).

The data may not characterize all Tolo and Klicker soils of the study area because the sampling locations were restricted to occurrences of soils supporting relatively uniform forest vegetation. The dominant trees encountered on these soils included ponderosa pine (*Pinus ponderosa* Laws.), grand fir (*Abies grandis* (Dougl.) Lindl.), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Biessn.) Franco), lodgepole pine (*Pinus contorta* Dougl.), and western larch (*Larix occidentalis* Nutt.).

Sampling was performed in the northern portion of the Starkey Experimental Forest and Range, 30 miles southwest of La Grande, Oregon. The soils were mapped earlier in a soil survey[1/] and associated vegetation was described by Strickler (1965). Starkey is in the central Blue Mountains, a faulted, uplifted, and dissected tertiary basalt formation. A volcanic ash mantle of varying thickness (20-90 centimeters) overlies portions of the area, generally on moderately sloping plateaus, north and east slopes, and some toe slopes of other exposures. Starkey contains 29,000 acres, of which 21,000 acres are forested and include 19,500 acres mapped as Tolo or Klicker series and closely related complexes.

Klicker soils have developed principally on south and west exposures from basalt residuum with some surface influence of ash and loess. They have medium surface textures, moderately fine to fine subsoil textures, and are influenced by rock and gravel throughout the profile.

Tolo soils are generally found on north and east exposures and are derived from volcanic ash which overlies older loess and residuum from basalt. Surface textures are medium, and little change occurs through the profile until the older material is encountered which has medium to fine textures. Rock and gravel influence is generally less than in Klicker soils. The two soils

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[1/] Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. Unpublished report issued by Soil Conservation Service and Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, 32 p., 1960.

are associated together geographically and with the Rock Creek, Albee, and Couse series. Both Tolo and Klicker soils can occur in nearly all topographic positions.

Precipitation averages 20 inches and is principally distributed over late fall, winter, and spring; a pronounced summer drought is characteristic. Hence the soils are usually moist but are dry in the 10- to 30-centimeter depth for 60-80 consecutive days during summer and fall. Elevation ranges from 3,800 to 5,000 feet, the mean annual temperature is about 6°-7°C (42°-45°F), and the growing season varies from 60 to 120 days.

METHODS

Sample locations were established within homogeneous vegetation units in conjunction with research being conducted near Bally Mountain and on the upper Smith Creek watershed (secs. 16, 17, 18, 19, 20, 21, 28, 29 of T. 3 S., R. 34 E., Willamette prime meridian). Analytical samples were composites of the same depth obtained in increments from five random points along a 30-meter transect. Each point increment had equal volume in the composite. The depth increments used were 0-15, 15-30, 30-60, and 60-90 centimeters. Sample materials were air-dried and sieved (less than 2 millimeters) for subsequent chemical analysis.

Soil analyses included organic matter by the Walkley-Black method (Jackson 1958, p. 219-221), total nitrogen by Kjeldahl method (Jackson 1958, p. 187-190), extractable sodium and potassium by flame photometer, and extractable calcium and magnesium by versenate titration (U. S. Salinity Laboratory Staff 1954, p. 100-101). Available phosphorus was determined by the sodium bicarbonate extraction technique (Watanabe and Olsen 1965), and soil reaction was measured in 0.01 M calcium chloride. Carbon-nitrogen ratios were computed, assuming organic matter averages 58-percent carbon content. Calcium-magnesium ratios were calculated from exchangeable quantities of each.

RESULTS

Means with a 95-percent confidence interval, ranges, and coefficients of variation of properties of Klicker and Tolo soil groups were determined (tables 1 and 2). The confidence interval offers an index of precision of the estimated mean. Values of zero for coefficients of variation and for confidence intervals occurred when the rounded results of analyses or calculations were less than the level of precision used for the means. Shallow soil and associated subsoil rock precluded sampling to 90 centimeters at some locations, so fewer observations are available for the two deepest sampling increments.

The least variable property measured in both soils was pH, which averaged from 5.4 in surface soils to 5.6 in subsoils. Earlier pH measurements at other locations of study soils and of additional forest and grassland soils were similar to these values (Geist and Strickler 1970).

Table 1.--Klicker soil chemical properties

Soil depth (cm)	Number of observations	pH	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
			Percent			*P/m*	*Meq/100 g*					
					Means[1/]							
0-15	17	5.4 ± 0.1	4.12 ± 0.57	0.11 ± 0.01	21 ± 1	47 ± 7	1.5 ± 0.2	0.1 ± 0.0	11.3 ± 1.1	2.6 ± 0.4	15.5 ± 1.4	5 ± 1
15-30	17	5.5 ± .1	2.28 ± .42	.07 ± .01	18 ± 2	34 ± 8	1.2 ± .2	.1 ± 0	10.8 ± 1.1	3.0 ± .4	15.1 ± 1.2	4 ± 1
30-60	13	5.5 ± .1	1.47 ± .37	.05 ± .01	16 ± 2	27 ± 6	1.0 ± .2	.2 ± 0	12.0 ± 2.0	4.4 ± .9	17.6 ± 2.5	3 ± 1
60-90	5	5.6 ± .1	.81 ± .34	.04 ± .01	14 ± 5	14 ± 7	.8 ± .3	.2 ± .1	14.3 ± 6.6	7.0 ± 3.7	22.3 ± 10.2	2 ± 1
					Ranges							
0-15	17	5.0-5.7	2.66-6.83	0.08-0.17	17-24	26-70	0.7-2.2	0.1-0.1	8.3-15.7	1.4-3.9	12.5-21.1	3-7
15-30	17	5.3-5.7	1.31-4.26	.05- .11	13-24	17-68	.6-1.5	.1- .2	7.8-14.8	2.1-4.4	11.8-18.6	2-7
30-60	13	5.3-5.7	1.08-3.23	.04- .10	13-21	15-44	.7-1.6	.1- .2	8.3-17.1	2.6-6.7	12.4-24.4	2-5
60-90	5	5.5-5.7	.47-1.23	.02- .04	11-20	7-21	.5-1.1	.1- .3	8.8-22.1	3.6-10.7	13.7-34.0	2-3
					Coefficients of variation (percent)							
0-15	17	3	27	24	9	29	27	0	19	27	17	29
15-30	17	2	36	25	19	43	25	35	20	24	15	33
30-60	13	2	42	33	16	38	26	31	27	33	24	33
60-90	5	2	34	25	26	42	29	37	37	43	37	23

[1/] ± 95-percent confidence interval.

Table 2.--Tolo soil chemical properties

Soil depth (cm)	Number of observations	pH	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
			Percent			*P/m*	*Meq/100 g*					
					Means[1/]							
0-15	24	5.4 ± 0.1	3.37 ± 0.36	0.09 ± 0.01	22 ± 1	63 ± 9	1.1 ± 0.2	0.1 ± 0.0	6.2 ± 0.9	1.2 ± 0.1	8.6 ± 1.2	5 ± 1
15-30	24	5.5 ± .1	1.74 ± .21	.06 ± .01	18 ± 1	36 ± 7	1.0 ± .1	.1 ± 0	5.2 ± .6	1.1 ± .2	7.4 ± .8	5 ± 1
30-60	24	5.5 ± .1	1.12 ± .17	.04 ± 0	18 ± 2	20 ± 4	.9 ± .1	.2 ± 0	6.8 ± .9	1.8 ± .6	9.7 ± 1.6	5 ± 1
60-90	20	5.5 ± .2	.60 ± .06	.03 ± 0	12 + 1	12 ± 2	.8 ± .1	.3 ± .1	10.6 ± 1.6	3.8 ± 1.0	15.5 ± 2.7	3 ± 1
					Ranges							
0-15	24	5.1-5.9	1.73-5.00	0.05-0.12	17-32	30-111	0.6-1.9	0.1-0.1	3.5-9.8	0.8-1.8	5.1-13.5	3-10
15-30	24	5.1-5.8	1.14-3.45	.04- .09	14-32	16-76	.5-1.5	.1- .2	3.2-8.3	.6-2.7	4.3-11.5	3-9
30-60	24	4.7-5.8	.72-2.29	.03- .06	12-33	5-47	.5-1.3	.1- .4	4.3-14.8	.6-8.7	5.6-24.6	2-7
60-90	20	4.7-6.6	.39- .86	.02- .04	9-16	3-21	.6-1.1	.1- .7	7.8-25.0	1.4-12.0	11.7-38.7	2-7
					Coefficients of variation (percent)							
0-15	24	4	25	22	15	34	35	0	35	21	32	32
15-30	24	3	28	21	19	48	29	26	28	41	27	28
30-60	24	5	37	22	25	51	22	38	32	85	38	33
60-90	20	7	21	21	18	37	16	48	33	56	37	36

[1/] ± 95-percent confidence interval.

Average organic matter and total nitrogen levels were higher in Klicker soils for all depths and also more variable than in Tolo soils. These mean levels were moderate and low, respectively, for the Klicker and Tolo soils. Concentrations declined rapidly with increasing soil depth in both soils. Ranges of organic matter contents extended rather high in both soil groups, up to the upper 6-percent level for the Klicker and the 5-percent level for the Tolo.

Average carbon-nitrogen ratios were similar for both soils; however, the Tolo soils showed wider ranges and more variable values than the Klicker. Both groups showed a consistent narrowing of the ratio from the surface depth down. This might be expected since the upper levels of the profile are most affected by root proliferation and organic matter deposition.

Available phosphorus averaged higher in the upper profile of the Tolo group and higher in the lower profile of the Klicker group, although levels in both soils declined with increasing soil depth. The variability of available P was generally higher and ranges were wider in the Tolo soils.

Both individual and total extractable cations, with two exceptions, averaged higher at all depths in the Klicker soils. In both soil groups, the calcium and magnesium levels commonly decreased slightly, then increased with depth as did the total cations. This trend was more pronounced for calcium. Sodium levels increased with increasing depth, while potassium decreased. The abrupt increase in extractable Ca, Mg, and total cations in the Tolo group is associated with the ash-basalt residuum lithologic discontinuity which occurred near the 60-centimeter depth. The percentages of individual cations of the totals for a given depth were similar between the two groups and showed similar trends, although trends appeared more pronounced in the Klicker soil group (table 3). Percentages gave a

Table 3.--Individual cation percentages of mean total extractable cations for Klicker and Tolo soils

Soil depth (cm)	Extractable cation			
	K	Na	Ca	Mg
	Percent			
Klicker soils:				
0-15	9	1	73	17
15-30	8	1	71	20
30-60	6	1	68	25
60-90	4	1	64	31
Tolo soils:				
0-15	13	1	72	14
15-30	14	1	70	15
30-60	9	2	70	19
60-90	5	2	68	25

different perspective of cation dynamics and indicated reverse trends to analytical values for calcium. Calcium and potassium percentages generally decreased with depth, whereas magnesium increased and sodium remained the same or increased slightly.

Calcium-magnesium ratios averaged slightly higher in the Tolo group and held at about a 5:1 level except at the 60- to 90-centimeter depth. This may reflect the influence of more clay in the lower profile. In contrast, Ca:Mg ratios in the Klicker soils steadily declined. A ratio between 1:1 and 5:1 is considered most desirable (Black 1965, p. 919).

At this point, the data were regrouped on the basis of dominant overstory species to see if analyses would reflect vegetative influences, and to provide a better opportunity for associating soils with the landscape. Three categories of dominant trees resulted: lodgepole pine, ponderosa pine, and mixed conifer (tables 4-7). The ponderosa pine group of soils was composed of one Tolo and 14 Klicker soils. The lodgepole pine group contained only Tolo soils, and the mixed conifer group contained three Klicker and 13 Tolo soils.

Because of the strong association of soil series and vegetation, many data for the vegetative groups were similar to those discussed above, not only in analytical trends but also in cation percentage trends. Differences among the new group means did occur, although the ranges associated with those means overlapped as noted with previous group means.

Soil reaction increased under lodgepole and ponderosa pine but decreased under mixed conifer with increasing soil depth.

Organic matter levels generally were higher in the ponderosa group, but less than 1-percent average difference occurred by depth among the three vegetative groups. Total N was also highest under ponderosa pine and lowest under lodgepole. Both total N and organic matter declined rapidly with depth. Calculated C:N ratios were very similar and declined with increasing depth.

Higher and more variable surface values were noted in available phosphorus under mixed conifer, while the other two groups were quite similar to each other. Rapid declines were noted in all three groups with increasing depth.

The lodgepole pine group was consistently lowest in mean extractable K, even though ranges overlapped. The average spread of 0.7 milliequivalents at the surface narrowed to 0.1 milliequivalents/100 grams at 60-90 centimeters. The mixed conifer and ponderosa group means were nearly identical. Extractable Ca was also lowest under lodgepole pine in the upper two depths.

Among the other extractable

Table 4.--Ponderosa pine group soil chemical properties

Soil depth (cm)	Number of observations	pH	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
			Percent			*P/m*	*Meq/100 g*					
					Means[1/]							
0-15	15	5.4 ± 0.1	4.04 ± 0.60	0.11 ± 0.01	22 ± 1	44 ± 7	1.5 ± 0.2	0.1 ± 0.0	10.6 ± 0.9	2.5 ± 0.4	14.7 ± 1.1	5 ± 1
15-30	15	5.4 ± .1	2.32 ± .48	.07 ± .01	20 ± 3	31 ± 7	1.2 ± .2	.1 ± 0	10.0 ± 1.0	3.1 ± .4	14.4 ± 1.3	3 ± 0
30-60	11	5.4 ± .1	1.34 ± .25	.04 ± 0	17 ± 3	25 ± 6	1.0 ± .2	.2 ± 0	11.1 ± 2.5	4.5 ± 1.1	16.8 ± 3.5	3 ± 0
60-90	4	5.6 ± .2	.82 ± .50	.04 ± .02	15 ± 6	15 ± 11	.9 ± .4	.3 ± .2	14.9 ± 9.2	7.7 ± 4.9	23.8 ± 14.0	2 ± 1
					Ranges							
0-15	15	5.0-5.7	2.66-6.83	0.08-0.17	19-24	26-68	0.7-1.9	0.1-0.1	8.3-14.0	1.2- 3.9	12.3-19.3	3-7
15-30	15	5.2-5.7	1.31-4.26	.05- .10	13-32	17-68	.6-1.6	.1- .2	7.8-12.7	1.6- 4.4	10.9-17.8	2-5
30-60	11	4.9-5.7	1.08-2.29	.04- .05	13-26	15-42	.7-1.4	.1- .2	7.0-17.1	2.1- 6.7	10.1-24.4	2-3
60-90	4	5.5-5.7	.47-1.23	.02- .04	12-20	7-21	.5-1.1	.1- .3	8.8-22.1	3.6-10.7	13.7-34.0	2-3
					Coefficients of variation (percent)							
0-15	15	3	27	23	7	29	24	0	16	32	14	31
15-30	15	2	37	23	24	43	25	46	18	26	16	25
30-60	11	4	28	11	23	38	23	23	33	35	31	17
60-90	4	2	38	25	25	44	29	33	39	40	37	25

[1/] ± 95-percent confidence interval.

Table 5.--Lodgepole pine group soil chemical properties

Soil depth (cm)	Number of observations	pH	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
			Percent			*P/m*	*Meq/100 g*					
					Means[1/]							
0-15	10	5.3 ± 0.1	3.62 ± 0.62	0.09 ± 0.01	24 ± 3	53 ± 9	0.8 ± 0.1	0.1 ± 0.0	4.4 ± 0.5	1.1 ± 0.1	6.4 ± 0.6	4 ± 0
15-30	10	5.5 ± .1	1.61 ± .20	.05 ± .01	18 ± 1	31 ± 7	.7 ± .1	.1 ± 0	4.6 ± .9	1.1 ± .4	6.5 ± 1.3	5 ± 1
30-60	10	5.6 ± .1	.90 ± .08	.03 ± 0	16 ± 2	16 ± 5	.8 ± .1	.2 ± .1	7.0 ± 2.0	1.9 ± 1.7	9.9 ± 3.9	5 ± 1
60-90	10	5.7 ± .3	.60 ± .11	.03 ± 0	13 ± 2	10 ± 2	.8 ± .1	.3 ± .1	11.3 ± 3.6	3.8 ± 2.1	16.2 ± 5.8	3 ± 1
					Ranges							
0-15	10	5.1-5.4	2.29-5.00	0.06-0.11	20-32	37-70	0.6-1.0	0.1-0.1	3.5-5.8	0.8-1.4	5.1- 8.0	3-5
15-30	10	5.3-5.7	1.17-2.11	.04- .07	14-21	18-48	.5-1.0	.1- .2	3.2-7.5	.6-2.7	4.3-11.0	3-6
30-60	10	5.4-5.8	.72-1.10	.03- .04	12-20	5-27	.5-1.1	.1- .4	4.3-14.8	.6-8.7	5.6-24.6	2-7
60-90	10	5.1-6.6	.39- .86	.02- .04	9-16	3-14	.6-1.0	.1- .7	7.8-25.0	1.4-12.0	11.7-38.7	2-7
					Coefficients of variation (percent)							
0-15	10	3	24	16	15	24	15	0	15	17	13	14
15-30	10	2	17	15	11	32	22	32	26	54	28	24
30-60	10	2	13	11	16	40	22	46	39	127	55	31
60-90	10	7	25	21	17	30	18	55	44	79	50	48

[1/] ± 95-percent confidence interval.

Table 6.--Mixed conifer group soil chemical properties

Soil depth (cm)	Number of observations	pH	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
			Percent			*P/m*	*Meq/100 g*					
						Means[1/]						
0-15	16	5.6 ± 0.1	3.38 ± 0.52	0.10 ± 0.01	20 ± 1	70 ± 11	1.5 ± 0.2	0.1 ± 0.0	8.7 ± 1.8	1.5 ± 0.4	11.8 ± 2.3	6 ± 1
15-30	16	5.5 ± .1	1.86 ± .31	.06 ± .01	18 ± 1	41 ± 10	1.2 ± .1	.1 ± 0	7.0 ± 1.9	1.3 ± .3	9.6 ± 2.3	5 ± 1
30-60	16	5.4 ± .1	1.38 ± .35	.05 ± .01	18 ± 3	24 ± 7	1.0 ± .1	.2 ± 0	8.0 ± 1.7	2.0 ± .4	11.2 ± 2.0	4 ± 1
60-90	11	5.4 ± .2	.61 ± .07	.03 ± 0	11 ± 1	13 ± 3	.8 ± .1	.3 ± .1	10.1 ± .8	3.9 ± .4	15.1 ± 1.0	3 ± 0
						Ranges						
0-15	16	5.4-5.9	1.73-5.43	0.05-0.16	17-25	30-111	1.0-2.2	0.1-0.1	4.6-15.7	0.9-3.2	6.7-21.1	4-10
15-30	16	5.1-5.8	1.14-3.48	.04- .11	13-21	16-76	.9-1.6	.1- .2	3.5-14.8	.7-2.6	5.4-18.6	4-9
30-60	16	4.7-5.7	.79-3.23	.03- .10	13-33	11-47	.8-1.6	.1- .3	4.4-14.4	1.1-3.4	7.4-18.9	2-7
60-90	11	4.7-5.7	.44- .75	.03- .04	9-15	7-21	.7-1.1	.2- .4	8.5-11.6	3.1-5.1	12.8-17.7	2-4
						Coefficients of variation (percent)						
0-15	16	2	29	28	10	31	27	0	39	51	37	29
15-30	16	3	31	28	13	48	19	24	51	45	45	32
30-60	16	5	47	34	27	51	21	31	39	37	34	30
60-90	11	6	17	15	16	37	14	26	12	15	10	20

[1/] ± 95-percent confidence interval.

Table 7.--Individual cation percentages of mean total extractable cations according to plant community divisions

Soil depth (cm)	Extractable cation			
	K	Na	Ca	Mg
	Percent			
Ponderosa pine:				
0-15	10	1	72	17
15-30	8	1	69	22
30-60	6	1	66	27
60-90	4	1	63	32
Lodgepole pine:				
0-15	12	1	70	17
15-30	11	1	71	17
30-60	8	2	71	19
60-90	5	2	70	23
Mixed conifer:				
0-15	13	1	73	13
15-30	12	1	73	14
30-60	9	2	71	18
60-90	5	2	67	26

cations, sodium values differed little among soils in both level and profile trends. Extractable Mg and total cations showed some similar trends among the three groups. However, a decline and rise in cations did not occur in the lodgepole group and differed in degree in the others. Mean values were generally lower under lodgepole and higher under ponderosa pine. Little difference was noted in Ca:Mg values. Percentages of the total cations for Ca and K decreased with depth whereas Mg increased. The latter values may reflect relative mobilities of these exchangeable ions.

DISCUSSION

Data reported for the Klicker and Tolo soils indicated considerable overlapping in the ranges of all properties at all depths. There were differences between calculated means of certain chemical characteristics; the larger differences were associated with organic matter, total nitrogen, available phosphorus, extractable calcium, magnesium, and total extractable cations. Overlapping between soil groups for a given soil property and depth is partially explained by the fact that soils are not distinct entities but are a part of a continuum of gradual change upon which classification boundaries are superimposed. Further, where soils are associated geographically, some similarities would be expected.

It appears advantageous to try grouping soils by means other than classification criteria, since soil-vegetation relationships may be revealed. For example, mean pH decreased with increasing soil depth in the mixed

conifer group but increased in other soil and vegetative groups. Also, organic matter and total N levels declined faster with depth in the lodgepole pine group than in other vegetative groupings considered. This latter trend and the seemingly lower nutrient status reflected in many of the analyses suggest that these lodgepole pine plant communities may be either low cyclers of certain nutrients and organic matter or are adapted to low fertility sites. (The possible role of fire cannot be ignored, although all soils examined in this study contained charcoal.) Nutrient concentrations in the ponderosa pine group averaged highest in most cases.

Considerable variability in soil properties within overstory strata suggested that differences in the understory vegetation might affect soil chemical properties. Future studies should investigate this aspect of soil-plant relations. Knowledge of conditions favoring key wildlife habitat or recreation species, as well as general ecological knowledge, should accrue from such a study.

Topsoil of both Tolo and Klicker soils is of management concern; analytical data illustrate why. Organic matter, total nitrogen, and available phosphorus levels declined rapidly from surface to subsoil depths in all cases. Hence, the topsoil represents the major source of N and P and other nutrients present mainly in organic matter. Topsoil losses due to accelerated surface erosion, machine slash piling, road building, landing construction, etc., could certainly reduce site productivity.

General fertility levels in the Tolo soils were lower than in the Klicker soils. This observation is based on expressions of nutrient concentration rather than quantity, and since Tolo soils are generally deeper they may, in contrast, contain total amounts similar to the Klicker soils. The relative importance of amounts as opposed to concentrations of nutrients is associated with root distribution and abundance for a given plant in a particular profile section. These factors are unknown, although many grasses and forbs root primarily in the surface soil. Hence nutrient concentrations may be more important in understanding production, quality, ecology, etc., of these species than others with widely distributed root systems.

All carbon-nitrogen ratios fell within a range where nitrogen mineralization would exceed immobilization during decomposition of existing organic matter. Incorporating new organic residues with high C:N ratios would immobilize mineral nitrogen during decomposition until the ratio of the residue is lowered to about 30:1. The amount and rate of immobilization and its impact on the soil-plant nutritional system depends on size, amount, degree of mixing, and nature of the residue as well as the residue C:N ratio. Woody residues (C:N = 100+) are relatively resistant to microbial attack; hence the amount of N immobilized per amount of residue is considerably less than readily decomposable

plant residues, particularly at first (Bartholomew 1965). Lignin in woody matter apparently retards decomposition of cellulosic materials through both its resistance to degradation and its close structural linkage with cellulose in the cell wall (Alexander 1961). The influence of slash from thinned trees and root decomposition on soil nitrogen has been considered in detail by Cochran (1968).

We do not have fertilizer guides for perennial vegetation in the Blue Mountains. Thus, the manager must depend on tissue symptoms of nutrient deficiency or past fertilization experience. Where nitrogen deficiencies are observed and fertilizer nitrogen is added to Tolo or Klicker soils to augment native N supply, nutrient responses on topsoils have shown that sulfur should be included in the fertilizer material. The sulfur prevents a nutrient imbalance and increases the efficiency of fertilizer N use. Phosphorus analyses indicated adequate levels in the surface soils studied; however, in degraded or severely disturbed situations where exposed subsoils require rehabilitation, application of N, S, and P may be valid (Geist 1971). Calcium, magnesium and potassium appeared adequate, although K may be limiting at the 0.5 meq/100 g level in Tolo soils under intensive production of high base-requiring crops such as grasses.

The variability noted in chemical properties is a signal to those working with Tolo and Klicker soils that visually selecting sampling locations is difficult because wide fertility differences may exist and should be accounted for. The rapid change in chemical soil properties from the surface down should also alert the sampler to carefully control penetration of the sampling device. Such chemical changes are frequently associated with changes in physical properties as well.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Nutrient concentration levels were generally lower in Tolo soils (volcanic ash-derived) than in Klicker soils (basalt-derived). Coefficients of variation of nutrient levels were fairly similar between soils and fluctuated with the chemical characteristic and soil depth considered.

Maintaining topsoil is important for nutrient supply in both soils but appears more critical in Tolo soils, particularly under lodgepole pine overstory. Stockpiling and subsequently restoring topsoil should be beneficial in rehabilitating heavily disturbed sites (log landings, slash piling areas, etc.).

Stratification of data according to overstory vegetation types appeared advantageous in terms of better understanding of soil-plant relationships including possible nutrient cycling differences. This also offers greater ease in relating soils data to vegetative mapping units. Study of understory vegetation relationships to soil chemical properties was indicated.

Rapid changes in chemical

characteristics within the soil profile showed the need for rather precise control of sampling depth. This will be of specific importance to soil surveyors and engineering personnel.

In developing fertilization guides, sampling procedures must account not only for inherent nutrient variation among soils, but also for the contrasting distribution patterns among nutrients with soil depth (e.g., as N and P decreased, K, Ca, and Mg increased). Differences in rate of change as well as direction of change were noted.

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P.O. Box 3141
Portland, Oregon 97208

GPO 990-071